Autonomous Propellant Loading Project

Completed Technology Project (2014 - 2016)

500 gallon composite tank ready to test to failure

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Project Introduction

The AES Autonomous Propellant Loading (APL) project consists of three activities. The first is to develop software that will automatically control loading of cryogenic propellant into launch vehicles to ensure safe and successful propellant loading.

The second part of the project is to build a system to demonstrate zero-loss cryogenic propellant (liquid hydrogen) transfer and storage, hydrogen liquifaction, and liquid hydrogen densification.

The third area is developing systems to develop technologies to monitor the status of composite tanks used to store cryogenic propellants to ensure they are safe to use.

This project builds on the AES Integrated Ground Operations Demonstration Unit (IGODU) project.

The APL project consists of three activities: autonomous control software; demonstrating cryogenic zero-loss transfer and storage, liquifaction, and densification; and developing techniques to monitor composite cryogen storage tanks. As well as being used on Earth, these technologies can be used as part of in situ resource utilization (ISRU), for example to liquify, densify, store, and transfer cryogenic propellants produced on Mars to return astronauts to Earth.

Autonomous Control Software:

The autonomous control software contains a physics-based model of the expected system operation. If the inputs from sensors do not agree with the expected system state, the software will determine and initiate the appropriate steps needed to either keep the system operating safely or shut it down safely. This allows the software to perform reasoning based on sensor inputs to determine the causes of anomalies and take appropriate actions. These actions may include reconfiguring the system or safely shutting it down.

Initially, the software will be tested using the Universal Propellant Servicing System (UPSS), a small launch vehicle facility being built at Kennedy Space Center (KSC). Once demonstrated on UPSS, the technology is anticipated to be infused into the Space Launch System (SLS) vehicle.

Ground Operations Demonstration Unit for Liquid Hydrogen (GODU LH2)

During the Space Shuttle program, engineers at KSC discovered that over 50% of the LH2 purchased by NASA was lost from the time it was loaded onto a tanker, offloaded into a storage container at KSC, transferred from the storage container to the Space Shuttle External Tank and the Space Shuttle launched. This part of APL is to eliminate the losses and enhance liquid hydrogen production and storage by:

- Demonstrate zero-loss transfer of LH2 during tanker offload, which has the potential to reduce future SLS LH2 procurement costs by at least 25%
- Demonstrate in-situ liquefaction of LH2
- Demonstrate densification of LH2, which has the potential to improve overall launch vehicle ascent performance by 10% or more.

Tank Health Monitoring (THM)

NASA's future goal of exploring the solar system by traveling beyond low Earth orbit with human missions requires new technologies to reduce weight. One technology being investigated for both structural members and propellant tanks is carbon composites. To ensure safety, the failure modes of tanks must be understood. Health monitoring technology is being developed for both structural members and propellant tanks to understand the mechanics and provide a detection system to prevent unexpected catastrophic failure.

The overall goal of the project is to test composite tanks under cryogenic temperatures to failure in order to develop health monitoring technology that will detect system degradation and mitigate catastrophic failures through improved system health insight.

Anticipated Benefits

This technology should reduce the number of people needed to load cryogenic propellants into launch vehicles as well as increase safety.

If used for launch vehicles, this technology should reduce the number of people needed to load cryogenic propellants into launch vehicles as well as increase safety.

Organizational Responsibility

Responsible Mission Directorate:

Exploration Systems Development Mission Directorate (ESDMD)

Lead Center / Facility:

Kennedy Space Center (KSC)

Responsible Program:

Exploration Capabilities

Project Management

Program Director:

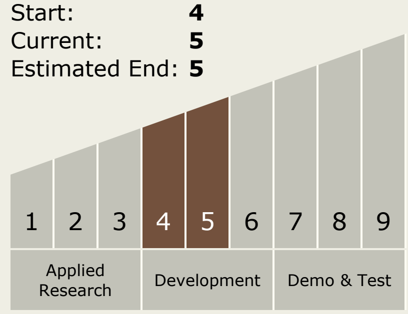
Christopher L Moore

Project Manager:

John S Gurecki

Technology Maturity (TRL)

Start: **4**
Current: **5**
Estimated End: **5**



Technology Areas

Primary:

Continued on following page.

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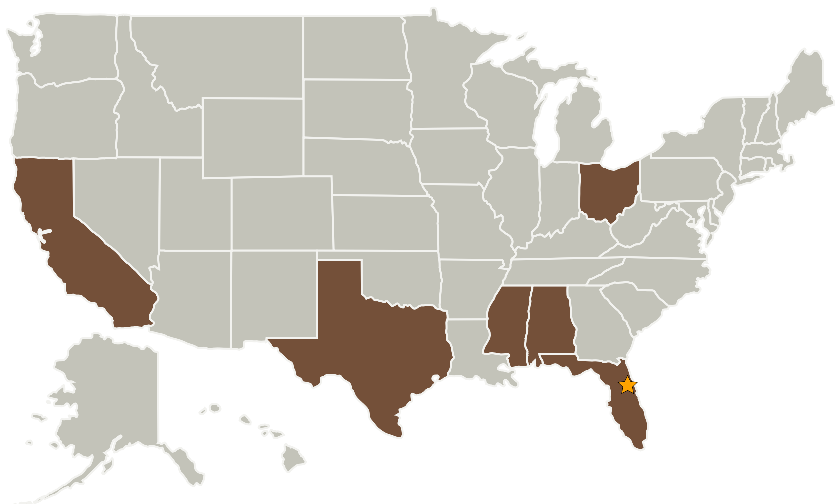
Completed Technology Project (2014 - 2016)

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
★Kennedy Space Center(KSC)	Lead Organization	NASA Center	Kennedy Space Center, Florida

Primary U.S. Work Locations	
Alabama	California
Florida	Mississippi
Ohio	Texas

Project Transitions

October 2014: Project Start

Technology Areas *(cont.)*

- TX13 Ground, Test, and Surface Systems
  └ TX13.1 Infrastructure Optimization
    └ TX13.1.4 Propellant Production, Storage and Transfer

Target Destinations

Mars, Others Inside the Solar System

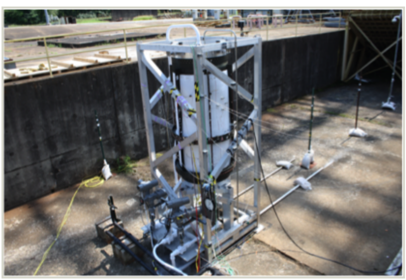
Supported Mission Type

Projected Mission (Pull)

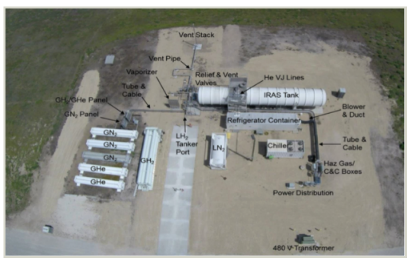
September 2016: Closed out

Closeout Summary: The Autonomous Propelant Loading project completed in FY16. There were three complementary tech nologies in the project: The first is to develop software that will automatically control loading of cryogenic propellant into la unch vehicles to ensure safe and successful propellant loading. The second part of the project is to build a system to demo nstrate zero-loss cryogenic propellant (liquid hydrogen) transfer and storage, hydrogen liquifaction, and liquid hydrogen de nsification. The third area is developing systems to develop technologies to monitor the status of composite tanks used to store cryogenic propellants to ensure they are safe to use. All three areas met their objectives. The automatic control softw are was demonstrated using a hardware simulated 3 stage launch vehicle. The system successfully loaded the three stage with no human intervention. This was done for routine loading as well as loading when system faults were inserted. In all c ases, the cryogenic loading was successful; when faults were introduced, the system automatically assessed the impacts of the faults and took appropriate action. In most cases, the action was to reconfigure the system to allow loading to continue and complete successfully. The liquid hydrogen system successfully demonstrated zero loss transfer of liquid hydrogen from a tanker truck to a storage tank, storage of the liquid hydrogen with no loss (boil off) of the hydrogen, liquefying gaseous h ydrogen, and densifying the liquid hydrogen to a slush. The tank health monitoring system has been tested by pressurizing tanks until they rupture and detecting the rupture points.

Images



Composte Tank Tank
500 gallon composite tank ready to test to failure
(https://techport.nasa.gov/image/36973)



Liquid Hydrogen test site
LH2 Test Site
(https://techport.nasa.gov/image/36972)